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Monthly Progress Report No. 4

System No. 2

Contract No. A-101

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1-0. PROJECT MEETING ON NAVIGATION FUNCTION OF SYSTEM NO. 2.

1-1. The essential features of the navigation function of System 2, described in Progress Report No. 3, were presented and discussed at a project meeting held on November 15, 1955. The system described uses ionospheric propagation in the high-frequency band to determine the aircraft position. Range, azimuth angle and elevation angle are measured from a single base station. Range is determined by measuring the total time required for a pulse to travel from the base station to the aircraft and for a response to travel from the aircraft to the base station. Azimuth and elevation angles are determined by measuring the average amplitudes of a series of pulses received at the aircraft from a reference antenna and two crossed antenna arrays.

1-2. With regard to the portion of the system which deals with angle measurements, the following points were discussed:

a. Base-station sites which would be free of interfering structures near the angle-data antenna installation are limited in number.

b. Pattern measurements outside of the base area would in some cases be very difficult to arrange.

c. The primary usefulness of the angle data is at ranges less than 1400 miles, since at greater ranges, conversion from radio range to ground range can be made to better than one percent range accuracy by estimating ionospheric reflection height.

d. Difficult engineering problems involved in constructing and phasing the angle-data antennas and in making pattern corrections may require more time for solution than is available before the operational date.

e. The rhombic antenna gain is not available during the angle-data measurement and improvement of the signal-to-noise ratio by pre-detector integration of coded pulse trains is not possible because of amplitude errors introduced by interfering modes of propagation. Operation of this portion of the system would thus be limited to the shorter ranges unless more transmitter power were provided.

1-3. With regard to using only the ranging portion of the system as an interim navigation system, the following points were discussed:

a. For interim use, a rho-rho system which requires two base stations to be in radio contact with the aircraft would be acceptable.

b. Operation at ranges much less than 1500 miles would not be attempted unless E-layer propagation is the dominant mode.

c. The estimation of ionospheric height of reflection as part of the position computation at the control center would be an acceptable procedure. This estimate would be made on the basis of ionospheric predictions, the determination of ionospheric height at points between base stations by round-trip ranging, and the determination of ionospheric height from the radio range in cases where the aircraft position can be determined by other means.

2-0. PLANNING BASED ON PROJECT MEETING DISCUSSIONS.

2-1. In view of the apparent instrumental difficulties associated with radiation angle measurement and the comparative simplicity of radio-range measurements, major effort on the navigation system will be directed toward producing a breadboard ranging equipment to be used in conjunction with the communication system during flight tests. After this breadboard is completed, production design of a ranging system will be carried out to provide an interim rho-rho navigation system.

2-2. Investigation of radiation angle-measurement techniques and the preparation of experiments intended to provide information on the effects of other antennas and structures on the radiation pattern of an array of vertical radiators will continue.

3-0. PERFORMANCE OF A RANGING SYSTEM.

3-1. An approximate ranging equation for the spherical earth case is:

$$r = \left[\frac{L^2 - 4h^2}{1 + \frac{h}{R}} \right]^{\frac{1}{2}}$$

where
r = ground range
L = radio path length
h = height of reflection
R = earth radius

3-2. Using the above range expression, the error in range, as a function of the uncertainty in ionospheric height of reflection with constant radio path length, is

$$dr = -\left[\frac{4h}{r\left(1+\frac{h}{R}\right)} + \frac{r}{2R\left(1+\frac{h}{R}\right)}\right] dh$$

where dr = range error
dh = ionospheric height uncertainty

3-3. Curves showing this range error for E-, and F-region propagation with reflection heights of 60 miles (97 km) and 200 miles (322 km) and height uncertainties of 6 miles (10 km) and of 20 miles (32 km) respectively are shown in figure 1. It will be noted that the range uncertainty is substantially less than one percent of the range for one-hop F-region propagation at ranges greater than 1500 miles and only slightly greater than this for ranges near 2500 miles when two-hop propagation is necessary. In the less-than-1500-miles region, there is the possibility of obtaining a strong one-hop E modo, and if data are available to distinguish this, it is possible to operate at ranges less than 1500 miles. Curves showing range error for E-region propagation with a reflection height of 60 miles and an uncertainty of 6 miles indicate the excellent accuracy obtainable when E-region propagation is dominant.

4-0. <u>IONOSPHERIC HEIGHT DETERMINATION.</u>

4-1. Forecasts of heights of reflection may be made by the use of data published monthly in the CRPL-F bulletins. These give monthly median values for virtual heights of reflection, usually to an accuracy of ± 10 km, as observed at ionospheric laboratories throughout the world. The particular locations at which observations, of interest here, are regularly obtained are Japan, Formosa, Singapore, India, Austria, England, Scotland, and Sweden. While these do not provide the geographical coverage which might be desired, they still represent a fairly representative sample to which corrections for time of day, latitude, and solar cycle variation may be applied to obtain predicted values at the particular points of interest.

4-2. Since the predicted values will be obtained in most cases from the monthly medians of daily observations, it is important to investigate the magnitude of the variations which may occur from day to day about this median. Ten curves of virtual height versus time of day chosen at random from curves obtained from measurements made at Washington D. C. during January, 1954, are shown in figure 2. Variations which are questionable due to high absorption, spread F, sporadic ionization, or any other reason are shown with dashed lines. Superimposed upon each curve is another representing the median variation with time of day for the entire month. It will be noted that only eight of the non-questionable values differ from the median curve by more than ± 20 km, and only one differs by more than ± 30 km. Also, it will be noted that, in general, even the questionable values are in good agreement with the median, although they were not used in obtaining the median. A similar check of variations of daily readings from the monthly median values for June, 1954, showed that a substantially larger percentage differed from the median by more than ± 30 km than was the case for January. In most cases these large variations coincided with periods of ionospheric and geomagnetic disturbance. However, unless additional data become available, it may be necessary to accept a greater ranging uncertainty during the summer months.

4-3. The position of the aircraft near the start of the flight may be determined by dead reckoning in order to determine an initial height of reflection. Heights of reflection at the midpoint of the path between stations, can be determined from ranging between base stations. Efficient operation of the system will require close correlation of all available data regarding reflection height, beginning with height predictions for the path obtained as outlined above. These will be corrected as indicated by the value obtained early in the flight, and re-corrected if necessary at any time during the flight when the pilot is able to obtain a visual position check.

4-4. The ranging system can be made to provide radio path ranges for up to three modes (if they are present) and to indicate which of the three modes has the largest amplitude. Prior to the flight, predictions will be made of the modes of propagation to be expected on all of the operating frequencies, as well as the time sequence in which the various modes are expected to be received when more than one mode is present. These predictions, together with the information from the system regarding radio-path ranges, should allow the various modes to be identified by using the criterion of consistency of ranges obtained for all modes. Furthermore, should one of these be a one-hop E mode or a two-hop E mode, its presence will allow an independent check of F-region reflection height since the E region is quite stable and supplies an excellent reference for this purpose. If E and F echoes are fading independently and are not always present simultaneously, the active mode may be identified by a check of the computed position against a position obtained by the use of dead reckoning to extrapolate the aircraft's path.

5-0. RANGING SYSTEM INSTRUMENTATION.

25X1X3

[redacted]

25X1X3

[redacted]

6-0. PROGRESS ACHIEVED ON THE COMMUNICATION PORTION OF SYSTEM NO. 2.

6-1. Work on the communication part of System 2 has progressed satisfactorily during the past month. There have been only minor changes in system structure since the last progress report and system development is progressing along the lines previously described.

6-2. So far the major emphasis has been on the airborne equipment since this equipment presents the most difficult packaging problem and since much of the circuitry of the base-station equipment will largely duplicate the circuitry of its airborne counterpart. Circuit design of the airborne components of the communication system is now 90% complete.

6-3. The only circuits of the airborne communication equipment whose design is not complete are the antenna coupler and the airborne power supply. Unexpected difficulties have caused delays in the design of these units. It is believed, however, that circuit design of these units will be completed within the next two weeks.

6-4. Package design of those units whose circuit designs are firm has been progressing during the past month. The layouts of the airborne-transmitter exciter, the receiver, and the airborne timing circuits are nearly complete and fabrication of these assemblies should begin shortly. Design of the airborne input mechanism and printer is approximately 50% complete. Present planning and progress indicates that most of the units will be completely assembled and ready for testing by 30 December, 1955.

6-5. Design of the base-station units which are not duplicates of airborne equipment has begun and is approximately 30% complete. This equipment will also be assembled and ready for testing on 30 December 1955.

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7-0. TOTAL MAN-HOURS EXPENDED. A total of [redacted] man-hours has been expended on System No. 2 (navigation portion and communication portion) during the period covered by this progress report.

[redacted]